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| (54) Title: IMMUNO-REACTIVE PEPTIDE CTL EPITOPES OF HUMAN CYTOMEGALOVIRUS | | | |
| (57) Abstract | | | |
| <p>The invention provides a plurality of peptides (and immunologically functional variants thereof) which are immunogenic epitopes recognized by CD8⁺ class I MHC restricted cytotoxic T-lymphocytes of patients harboring latent cytomegalovirus (HCMV) infection. The peptides are capable of activating CTLs and CTLp's in the absence of active viral replication, and thus are useful for eliciting a cellular immune response against HCMV by normal and immunodeficient subjects. Polypeptide and lipopeptide vaccines, with and without adjuvants, also are disclosed.</p>  | | | |

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IMMUNO-REACTIVE PEPTIDE
CTL EPITOPES OF HUMAN CYTOMEGALOVIRUS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of co-pending application serial no. 08/747,488, filed November 12, 1996.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was made with government support in the form of grant no. CA30206 from the United States Department of Health and Human Services, National
5 Cancer Institute. The government may have certain rights in the invention.

BACKGROUND OF THE INVENTION

1. Technical Field

10 This invention relates to human cytomegalovirus (HCMV), and in particular to peptide fragments from a single subunit protein that function as T-cell epitopes of HCMV in human beings. The peptide fragments are capable of directing human cytotoxic T lymphocytes
15 (CTL) to recognize and lyse human cells infected with HCMV. The peptide fragments can independently direct HCMV-specific CTL to lyse cells incubated with the peptide and which express HLA A, B or C genes.

2. Description of the Background Art

The HCMV genome is relatively large (about 235k base pairs) and has the capacity to encode more than two hundred proteins. HCMV is composed of a nuclear
5 complex of nucleic acid (double-stranded DNA) surrounded by capsid proteins having structural or enzymatic functions, and an external glycopeptide- and glycolipid-containing membrane envelope. HCMV is a member of the herpes virus family and has been
10 associated with a number of clinical syndromes.

HCMV infection is relatively common and is usually self-limiting in the healthy, immunocompetent child or adult (L. Rasmussen, Curr. Top. Microbiol. Immunol. 154:221-254, 1990). Approximately ten percent (10%) of
15 all newborn infants carry HCMV and the virus can cause severe congenital disease in the fetus or infant. Some of these newborn infants suffer congenital birth defects. Other newborn infants carry cytomegalovirus for some time before they actually show symptoms of the
20 disease. For example, HCMV is a common cause of mental retardation in children who acquire the infection in utero from mothers carrying an active infection.

Several studies have begun to question whether persistent and apparently asymptomatic HCMV infection
25 in an otherwise healthy adult poses health risks in certain individuals. For example, individuals who have undergone coronary angioplasty sometimes subsequently develop restenosis as a result of arterial remodeling. In one study, about one third of such patients with
30 restenosis had detectable HCMV DNA in their arterial lesions (E. Speir et al., Science 265:391-394 (1994)), whereas in another study CMV seropositive patients were five times more likely to develop restenosis than their seronegative counterparts (Y.F. Zhou et al., New
35 England J. Med. 335:624-630 (1996)). These studies

suggest that decreasing the number of HCMV infected host cells can benefit certain individuals.

HCMV also has been associated with morbidity and mortality in immuno-compromised patients. HCMV is an
5 important consideration in the treatment of patients suffering from Acquired Immunodeficiency Syndrome (AIDS). The defining complication is retinitis, which, if left untreated, can lead to blindness. Historically, CMV disease has been one of the more
10 devastating of the opportunistic infections (OI) that beset HIV-1-infected individuals whose CD4⁺ T cell level diminishes below 100/mm³. Other disease manifestations of CMV viremia also appear as the CD4⁺ T cell counts drops below 100/mm³, including encephalitis, enteritis
15 and pneumonia. At autopsy there is multi-organ involvement of CMV disease in the preponderance of AIDS patients who had severe CMV retinitis.

Patients infected with HCMV often suffer impairment of some of their vital organs, including the
20 salivary glands, brain, kidney, liver and lungs, as a result of the effects of the disease. Furthermore, HCMV is associated with a wide spectrum of classical syndromes including mononucleosis and interstitial pneumonia. HCMV also has an oncogenic potential and a
25 possible association with certain types of malignancies including Kaposi's sarcoma.

HCMV can cause opportunistic infections resulting in a variety of complications in, for example, immunosuppressed organ transplant patients. Prior to
30 the use of antiviral chemotherapy, HCMV infection had been responsible for a substantial proportion of post-bone marrow transplantation (BMT) complications (J. Meyers et al., J. Infect Dis. 153:478-488 (1986)). The advent of drugs such as ganciclovir with substantial
35 anti-CMV activity dramatically reduced complications

associated with post-BMT CMV infections (G. Schmidt et al. New England J. Med. 324:1005-1011 (1991) and J.M. Goodrich et al., New England J. Med. 325:1601-1607 (1991)). Ganciclovir is most effective when
5 administered prophylactically before diagnosis of HCMV infection. This approach has several negative aspects including a higher proportion of recipients becoming neutropenic (one third) and increased numbers of
10 concomitant fatal bacterial and fungal diseases (J.M. Goodrich et al., Ann. Intern. Med. 118:173-178 (1993)). An alternative approach in which ganciclovir was given when HCMV antigens or DNA are first detected by culture methods provided no survival advantage compared to
15 prophylaxis or treatment post-disease for all patients (D.J. Winston et al., Ann. Intern. Med. 118:179-184 (1993)). Finally, because of the acute nature of the side-effects, there is a need for increased hospitalization and growth factor administration to treated patients which, coupled with the cost of
20 ganciclovir prophylaxis, increases the cost of BMT after-care.

Because human cytomegalovirus is relatively common, yet is associated with extremely serious health conditions, a considerable effort has been made to
25 study the biology of the virus with the aims of improving diagnosis of the disease as well as developing preventative and therapeutic strategies.

The mounting of a CD8⁺ CTL response is believed to be an important mammalian host response to certain
30 acute viral infections. The observations that HCMV infection is widespread and persistent, and may be reactivated and become clinically evident in the immunosuppressed patient, have suggested that virus-specific T-cells, including HCMV-specific CTL, play an

important role in the control of persistent infection and the recovery from CMV disease.

In humans, protection from the development of CMV disease in immunosuppressed BMT recipients correlates with the recovery of measurable CD8⁺ CMV-specific class I MHC-restricted T cell responses (Quinnan et al., N. Eng. J. Med. 307:7-13 (1982); Reusser et al., Blood 78:1373-1380 (1991)). These observations led investigators to carry out clinical trials in which donor-derived CMV-specific CD8⁺ CTL were infused into BMT recipients as an alternative to ganciclovir prophylaxis and therapy (S.R. Riddell et al., Science 257:238-241 (1992)). The transfer of CD8⁺ CTL clones to allogeneic bone marrow transplant recipients results in detectable CTL-based CMV immunity, and statistically significant diminution of CMV disease after BMT (E.A. Walter et al., N. Eng. J. Med. 333:1038-1044 (1995)).

Although successful in application, this approach has the disadvantage that it requires a sophisticated laboratory setup (which is also highly labor-intensive and costly) to derive the HCMV-specific CTL in vitro to be reinfused into a patient. A desirable alternative would be to deliver a vaccine derived from HCMV that would impart immunity to a BMT recipient, a solid organ recipient, a heart patient, an AIDS patient or a woman of child-bearing years, without the need for ex vivo expansion of HCMV-specific CTL. To develop such a vaccine, the viral proteins which cause the host to recognize HCMV in a protective manner must be identified, so that their amino acid sequence information can be determined. No such vaccine presently is available, however.

The viral life cycle provides insight as to the most effective time frame for targeting a vaccine to maximally disrupt virus production and spread.

Following HCMV entry into the host cell and uncoating, the viral genome is expressed sequentially via immediate early (0-2 hour), early (2-24 hour) and late (>24 hour) viral proteins. However, certain viral structural proteins such as pp65 are chaperoned into the cell because of their existence in large quantity in the viral particle. Much attention has focused upon structural virion proteins as potential immunodominant target antigens for HCMV-specific CTL responses.

One viral structural protein, pp65, has been identified as a target antigen for CMV-specific class I MHC restricted CTL derived from the peripheral blood of most asymptomatic CMV seropositive individuals (E. Mclaughlin-Taylor et al., J. Med. Virol. 43:103-110 (1994)). Importantly, CD8⁺ class I MHC restricted CTL specific for pp65 will recognize autologous HCMV-infected cells without the requirement for viral gene expression, presumably as a result of processing of the internal depot of pp65 that is transferred into the cell during infection (M.J. Gilbert et al., J. Virology 67:3461-3469 (1993)). CTL against pp65 or pp150 (another matrix protein that is recognized frequently) are able to recognize and lyse HCMV-infected cells in vitro within an hour of infection in the absence of viral gene expression (S.R. Riddell and P.D. Greenberg, Curr. Top. Microbiol. Immunol. 189:9-34 (1994)). Thus, these CTL may represent an important effector cell for limiting HCMV reactivation and progression to CMV disease, and such a cellular immune response in both immunocompromised and normal individuals would be extremely important (C.-R. Li et al., Blood 83:1971-1979 (1994)). Alternatively, CTL recognizing envelope proteins are not a substitute for pp65 and pp150 CTL because they are rarely found, arising late in infection and they are poor lytic effectors because of

the down-regulation of the required Class I MHC molecules (M.J. Gilbert et al., J. Virology 67:3461-3469 (1993)). Finally, the HCMV major protein IE, produced abundantly early after infection, is specifically inhibited from being a stimulator of CD8' CTL by a CMV-dependent blockade of its presentation (M. J. Gilbert et al., Nature [London] 383:720-722, 1996). Therefore, vaccines stimulating immunity against pp65 or pp150 would be the preferred mechanism for eliciting protective immunity against CMV infection.

It has been established that individual MHC Class I molecules preferentially bind peptides of a given motif and that the amino acid sequence of specific positions of the motif are invariant, allowing a given peptide to bind to MHC Class I molecules with high affinity. These are referred to as "anchor positions" (K. Falk et al., Nature 351:290-296 (1991)). Later studies have suggested that amino acid positions other than the anchor positions also contribute to the specificity of peptide binding to MHC Class I molecules. Additionally, residues at positions within the CTL epitope which do not interact with MHC may interact with T cells, presumably by binding the T Cell receptor (TCR). The binding of peptide amino acid residues to MHC or TCR structures is independently governed, so that substitution of TCR binding amino acid residues in many cases will not interfere with binding to the MHC molecule on the surface of an antigen presenting cell.

Edman degradation followed by N-terminal sequence analysis has been used to sequence the peptide mixture which is bound to the MHC class I peptide binding groove. In most cases the length of these peptides is between 9 and 11 amino acids. Mass spectrometry of HPLC separated peptide mixtures can elucidate the

primary sequence of individual peptides. Peptide fragments which bind to MHC identified in this manner are referred to as "naturally processed epitopes." Alternatively, one can predict which peptides of a given length, between 9-11 amino acids, will optimally bind to individual HLA Class I alleles based on their conformity to a motif (K. Falk et al., Nature 351:290-296 (1991)). One such motif has been established for HLA A*0201. Positions 2 and 9 of a nonapeptide are anchor residues for HLA A*0201, with minor contributions to binding from positions 1, 4, 3, 5, 6, 7, 8 in decreasing order of importance to binding strength (J.W. Drijfhout et al., Human Immunology 43:1-12 (1995)). Similar motifs have been established for decamers and undecamers for HLA A*0201. Correspondingly, unique amino acid motifs have been established for a subset of other HLA A and B alleles to predict binding peptides between 8-11 amino acids (H.G. Rammensee et al., Immunogenetics 41 (4):178-228 (1995)).

It is recognized that CTL are an important mechanism by which a mammalian organism defends itself against infection by viruses and possibly cancer. A processed form of, e.g., a viral protein minimal cytotoxic epitope (MCE) in combination with MHC Class I molecules is recognized by T cells, such as CD8⁺ CTL. Functional studies of viral and tumor-specific T cells have confirmed that an MCE of 8-12 amino acids can prime an antigen presenting cell (APC) to be lysed by CD8⁺ CTL, as long as the APC expresses on the cell surface the correct MHC molecule that will bind the peptide.

It has been shown that the route of entry of a protein into the cell determines whether it will be processed as an antigen bound to either MHC Class I or

II molecules. The endogenous or Class I pathway of protein degradation is often used by infectious viruses when they are present within cells. Viral nucleoproteins which may never reach the cell surface as full length molecules are still processed within the cell, and degraded portions are transported to the surface via MHC Class I molecules. Viral envelope glycoproteins, merely because they are cell surface molecules, do not obligatorily induce CTL recognition. Rather, it has been found that viral nucleoproteins, predominantly in the form of processed epitopes are the target antigens recognized by CD8⁺ CTL (A. Townsend et al., Philos. Trans. R. Soc. Lond. (Biol). 323:527-533 (1989)).

As it has become apparent that antigens entering the cell through exogenous pathways (pinocytosis, etc.) are not typically processed and presented by Class I MHC molecules, methods to introduce proteins directly into the cytoplasm have become the focus of vaccine developers. An approach that had gained favor was to use recombinant vaccinia viruses to infect cells, delivering a large amount of intracellular antigen. The enthusiasm for using vaccinia viruses as vaccines has diminished, however, because these viruses have the potential to cause disease in immunosuppressed people, such as BMT recipients. Another approach to vaccination is to mix an antigenic protein with an adjuvant and introduce the mixture under the skin by subcutaneous injection.

Yet another potential approach to immunization to elicit CTL is to use the MCE defined for a viral antigen in the context of a particular MHC restriction element to boost a CTL memory response to a virus. The ability of an MCE to provide protective immunity to challenge by a lethal dose of an infectious virus has

been discussed in the literature. Vaccine developers have developed increasing interest in utilizing the MCE as the vaccine because it is capable of binding to MHC Class I molecules through external binding of the cell surface molecules without the need for internalization or processing. The MCE has been most effective as an immunogen when synthesized as a lipidated peptide together with a helper CD4 epitope (A. Vitiello et al., J. Clin. Invest. 95:341-349 (1995) and B. Livingston et al., J. Immunol. 159:1383-1392, 1997). Other modifications of the bivalent vaccine include inclusion of a signal sequence (KDEL) for endoplasmic reticulum retention and targeting to attain maximum activity. There is also evidence in the literature that an MCE presented by particular types of APC (e.g. dendritic cells) may cause a primary immune response to occur in the absence of viral infection or prior contact with the virus or tumor cell.

Accordingly, in spite of significant efforts towards identifying the HCMV proteins that are recognized by CTLs, as well as the specific identification of the HCMV late structural protein pp65, improved methods of preventing and treating HCMV infection are needed. Introduction of CMV-specific CTL into a recipient is not a universally applicable and practical strategy to confer immunity to all those at-risk individuals who may need to be immunized against HCMV infection.

SUMMARY OF THE INVENTION

Accordingly, one aspect of the present invention relates to immunologically active peptides, and functional variants thereof, capable of eliciting a cellular immune response to HCMV in humans. The peptides are capable of directing human CTL to

recognize and lyse human cells infected with HCMV. Such immunologically active peptides, in association with an MHC Class I molecule, are recognized by CTLs of individuals having a latent (inactive) HCMV infection.

5 Another aspect of the present invention provides a method of augmenting the immune system of a patient in need thereof (i.e., a patient harboring a latent or active CMV infection) by administering at least one immunologically active peptide according to the present
10 invention that will be recognized by CTLs and/or CTLps (CTL precursors) of the patient.

In yet another aspect of the invention, at least one immunologically active peptide is administered to uninfected individuals to provide immunity against
15 future infections by HCMV. Such a peptide may be administered in the form of a peptide or lipopeptide vaccine, optionally with an adjuvant.

Alternatively, the peptide(s) may be administered in the form of a cellular vaccine via the
20 administration of autologous or allogeneic antigen presenting cells or dendritic cells that have been treated in vitro so as to present the peptide on their surface.

Yet another aspect of the invention is a method to
25 augment the immune response of an individual who is latently infected with CMV and is at risk for reactivation of CMV infection, wherein T cells are removed from an individual and treated in vitro with a peptide of the present invention. The resulting CMV-
30 reactive CTL are reinfused autologously to the patient or allogeneically to, for example, a BMT recipient.

In yet another aspect, a method to confer immunity against an HCMV infection to a previously uninfected individual includes the steps of removing T cells from
35 the individual, exposing the T cells in vitro to a

peptide of the present invention and then reinfusing the resulting HCMV-reactive CTL to the individual.

The peptides of the present invention also may be administered to previously infected or uninfected patients, or in vitro to T cells, in the form of a polynucleotide (DNA-based) vaccine, wherein a suitable gene transfer vector, such as a plasmid or an engineered viral vector that contains DNA encoding the peptide fragment under the control of appropriate expression regulatory sequences, is administered to the patient or to T cells in culture.

In yet another of its aspects, the present invention provides a vaccinia, canarypox or other eukaryotic virus vector containing a DNA sequence encoding the immunologically active peptide fragment. The vector infects an antigen presenting cell which in turn presents antigen that will be recognized by CTLs of patients having a latent (inactive) HCMV infection.

An additional aspect of the invention relates to diagnostic reagents for detection of the presence of active versus quiescent HCMV infections. The peptides according to the present invention can directly stimulate CTLp in vitro and therefore can be used in an assay to determine the degree of immunostimulation being caused by HCMV. The peptides can also be used to distinguish individuals who are seropositive from those who have not been exposed to HCMV (seronegative individuals). T cells from a patient can be contacted in vitro with APC that have been primed with a peptide according to the present invention.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 shows the effect of monolipidation and dilipidation of peptides in the presence and absence of adjuvant on the ability of the peptides to elicit a cytotoxic response.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to one aspect of the present invention, a nonapeptide (9 amino acid peptide) of the sequence
5 NLVPMVATV (pp65₄₉₅₋₅₀₃) (SEQ ID NO:1) is an immunogenic epitope of pp65 from CMV laboratory strains AD169 and Towne and all wild type isolates examined to date which is recognized by CD8⁺ Class I MHC restricted cytotoxic
10 T-lymphocytes of patients harboring latent CMV infection. The peptide is capable of activating CTLs in the absence of active viral replication, and thus is useful for augmenting the immune system of normal and immunodeficient patients, as well as in the study of the Class I antigen processing pathway for HCMV
15 proteins. The nonapeptide has amino acid residues in positions 2 and 9 which are the preferred residues at those positions for interaction with the HLA A*0201 and certain subtypes of HLA A*02XX, where XX= subtypes 02-22 (J.W. Drijfhout et al., Human Immunology 43:1-12
20 (1995)). Nonetheless, other less preferred amino acid residues may replace the preferred anchors, whereupon the peptide can continue to exhibit the capacity to bind HLA A*0201 and certain subtypes of HLA A*02XX with the ability to stimulate HCMV-specific CD8⁺ CTL.

25 Thus, in one aspect, the present invention provides an immunologically active peptide, capable of eliciting a cellular immune response to human cytomegalovirus infection, of the preferred sequence:

30 NLVPMVATV (SEQ ID NO:1).

Sequence variants of the preferred peptide include peptides of the sequence NX₁VPMVATX₂ wherein X₁ is L, I, M, T or V, and X₂ is V, A, C, I, L or T (SEQ ID NO:2).

35 The invention includes the construction and selection

of other functional sequence variants, which can be carried out by those skilled in the art based upon the present disclosure. The peptide or the structural variants disclosed herein also can be a functional part of a longer peptide which produces the immunological effects disclosed herein.

Other immunologically active peptides according to the present invention include the peptides:

10 YSEHPTFTSQY (SEQ ID NO:3)

which binds to HLA A*01XX including A*0101 and subtypes thereof. Sequence variants of this peptide include peptides of the sequence YXEHPTFTSQY wherein X is S, T or L (SEQ ID NO:4). The invention includes the construction and selection of other functional sequence variants, which can be carried out by those skilled in the art based upon the present disclosure. The peptide or the structural variants disclosed herein also can be a functional part of a longer peptide which produces the immunological effects disclosed herein.

FVFPTKDVALR (SEQ ID NO:5)

25 which binds to HLA A*68XX including A*6801 and subtypes thereof. Sequence variants of this peptide include peptides of the sequence FX₁FPTKDVALX₂ wherein X₁ is V or T and X₂ is L, R or K (SEQ ID NO:6). The invention includes the construction and selection of other functional sequence variants, which can be carried out by those skilled in the art based upon the present disclosure. The peptide or the structural variants disclosed herein also can be a functional part of a longer peptide which produces the immunological effects disclosed herein.

TPRVTGGGAM (SEQ ID NO:7)

which binds to HLA B*07XX including B*0701 and subtypes thereof. Sequence variants of this peptide include
5 peptides of the sequence TPRVTGGGAX wherein X is L, F, or M (SEQ ID NO:8). The invention includes the construction and selection of other functional sequence variants, which can be carried out by those skilled in the art based upon the present disclosure. The peptide
10 or the structural variants disclosed herein also can be a functional part of a longer peptide which produces the immunological effects disclosed herein.

FPTKDVAL (SEQ ID NO:9)

15

which binds to HLA B*35XX including B*3502, B*3504, B*3506 and other subtypes thereof with compatible peptide binding sites. The invention includes the construction and selection of other functional sequence
20 variants, which can be carried out by those skilled in the art based upon the present disclosure. The peptide or the structural variants disclosed herein also can be a functional part of a longer peptide which produces the immunological effects disclosed herein.

25

Example 1. Derivation of T-cell Clones

Methods for deriving T-cell clones from CMV seropositive individuals have been described in the
30 literature (see above references). Forty to fifty milliliter samples of whole peripheral blood were obtained from CMV seropositive volunteers (detected by standard antibody methods). The white blood cells (WBCs) were separated using Ficoll-HyPaque (DuPont)
35 density gradient centrifugation. The whole blood was

first centrifuged for 10 minutes at 1400 rpm in a tabletop centrifuge to reduce the number of red blood cells. The buffy coat was diluted to 12 ml with phosphate buffered saline (PBS), and 6 ml were layered on top of $\frac{1}{2}$ volume of Ficoll-HyPaque. The top layer was removed after centrifugation at 2000 rpm in a tabletop centrifuge for 15-30 minutes. The interface containing the WBC was removed, diluted in PBS and recentrifuged for 8-12 minutes at 1000 rpm, which caused the WBC to pellet. The cells were again resuspended in PBS and washed as above one additional time. Four to five million WBC/ml were resuspended in T cell medium (TCM) with human serum obtained from pooled AB+ (blood group) CMV seronegative donors (HAB).

Example 2. Derivation of LCL Antigen-Presenting Cells

Simultaneously, an autologous antigen presenting cell line was prepared by Epstein Barr virus immortalization of PBL (see Current Protocols in Immunology, Unit 7.22, Wiley-Liss Press (1993)). Deriving the CTLs and antigen presenting cells from the same individual ensures HLA matching between the cell lines.

Example 3. In vitro Stimulation by HCMV

To initiate the in vitro stimulation of the WBC, a monolayer of autologous dermal fibroblasts obtained from the same volunteers as the WBC was established by plating the cells in 12-well plates at 10^5 cells/ml/well in DMEM-10% HAB for 24 hours. After 24 hours in culture the fibroblasts were infected with CMV virions (AD169 or Towne strain) for 2 hours at a multiplicity

of infection of between 1 and 5. The medium and virus were aspirated from the monolayer, and 1 ml of fresh DMEM-HAB was added. The monolayer was incubated in the medium for an additional 4 hours, following which time, the medium was aspirated. Two milliliters of medium containing 8-10 million WBCs were added per well containing CMV infected fibroblasts. The WBCs and fibroblasts were cultured in RPMI-1640 (Irvine Scientific) containing 50 U/ml penicillin, 50 µg/ml streptomycin, 4 mM L-glutamine, 25 µM 2-mercaptoethanol, 10 mM HEPES and 10% HAB (TCM-HAB). This was termed the first stimulation, and the cells were co-incubated for 7 days. TCM-HAB may be replaced if it becomes spent, or the culture may be expanded if there is vigorous cell growth.

The WBCs were re-stimulated on day 7 by plating onto a fresh monolayer of CMV-infected autologous fibroblasts prepared as described above. In addition, γ-irradiated (2500 rad) autologous PBL (5-fold over WBC) were added as feeder cells, and the medium was supplemented with recombinant IL-2 (10 IU/ml, Chiron-Cetus) on days 2 and 4 of this second stimulation. Wells which exhibit rapid cell growth require new medium containing IL-2 as the medium becomes spent.

After 12-16 days in culture, the cells were harvested and assayed for recognition of CMV matrix proteins in a chromium release assay (CRA). The CRA was performed by preparing APCs as target cells which are autologous or HLA-mismatched to the T-cell clone by infection with recombinant vaccinia viruses containing the DNA for HCMV proteins such as pp28 (pp28vac), pp65 (pp65vac) and ppl50 (ppl50vac) or wild-type virus strain WR.

After overnight infection, the APCs were incubated with chromium-51, and the assay was carried out as

described (Current Protocols in Immunology, Wiley-Liss Press, Unit 7.17, (1993)). In the CRA, the vaccinia-infected APC (target cells) were loaded with chromium-51 and then mixed with cells from the T-cell clone (effector cells). Preferably, the cells are mixed at a series of effector : target cell ratios varying, for example from 20:1 to 1:1. After a 4 hour incubation period, the medium in which the cells were incubated was harvested. The release of radioactivity into the medium (R_e) was quantitated with a gamma scintillation counter. The extent to which infected antigen presenting cells exhibit spontaneous lysis and the release of radioactivity (R_s) in the absence of CTLs was established for each virus vector. The maximum amount of radioactivity incorporated into and releasable by the target cells (R_{max}) was established by lysis of target cells in a detergent (1% Triton X100; Sigma) solution. Percentage cytotoxicity can be expressed as:

$$100 \times ((R_e) - (R_s)) / ((R_{max}) - (R_s)).$$

Assays were deemed unacceptable and were repeated unless spontaneous release (R_s) was less than 30%.

Analysis of the assay was as described, with a positive result indicated by specific recognition of pp65vac infected autologous APC. A positive result for pp65 indicates that, in the tested polyclonal population, there are T cells which recognize the pp65 HCMV protein expressed by the virus.

Example 4. Procedure for Identification of the CTL
Epitope

WBC stimulated two times by HCMV on dermal
5 fibroblasts were cloned by limiting dilution in 96 well
U-bottom plates as follows. After 2 HCMV stimulations,
the WBC were depleted of CD4⁺ T cells by incubation with
paramagnetic beads conjugated to anti-CD4 antibodies by
negative selection. The resulting population was
10 generally between 90-95% CD8⁺, a reliable T cell subset
marker, and generally 99% CD3⁺, a marker for most
peripheral blood T cells as assayed by either flow
cytometry or fluorescence microscopy. This final
population was plated at a concentration between 0.3-3
15 cells per well in a final volume of 150 μ l. Each well
also contained γ -irradiated $1.0-3.0 \times 10^5$ allogeneic
peripheral blood mononuclear cells (PBMC) in TCM-HAB
supplemented with 50-100 IU/ml recombinant IL-2
(Chiron-Cetus) and 0.5 μ g/ml PHA (Murex).
20 After 3 days of culture, the PHA was diluted 2-
fold by exchanging 75 μ l with fresh culture medium
supplemented with rIL-2. The wells were supplemented
with fresh rIL-2 every 3-4 days, and medium was
replaced as necessary. The cells were restimulated at
25 between 12-14 days with fresh allogeneic PBMC as
described above, and the plates were carefully observed
for growth in individual wells. Visible cell growth
indicates the need to transfer the expanding T cells to
larger wells. T cells were restimulated every two
30 weeks, and were transferred to progressively larger
wells. At the stage of accumulation of several million
cells, some were cryopreserved, and others were
subjected to a further CRA. In this CRA, the targets
were CMV infected fibroblasts, uninfected fibroblasts,
35 autologous LCL infected with wild type vaccinia or

vaccinia virus expressing either pp28, pp65 or pp150. HLA mismatched fibroblasts and LCLs were used as controls. One T cell clone among several tested, which was designated 3-3F4, had the characteristics of being both CMV and pp65-specific, and was reactive only to autologous targets in a specific manner. Other T cell clones with different HLA phenotypes were initially isolated in the same way, except that the initial peripheral blood sample came from different volunteers.

The HLA element which restricted the recognition of the T cell clone 3-3F4 to pp65 was identified. A series of LCL were used as targets that were singly autologous with each HLA allele of the 3-3F4 cell line. Each target was separately infected with pp65vac, wild type vaccinia, or not infected at all. The results showed that only the LCL that were autologous to the HLA A*0201 allele were being recognized and killed by the 3-3F4 T cell line. It was also established that 3-3F4 is of the CD8⁺ T cell subset, characteristic of CTL which recognize Class I restricted peptides. Whether the cell line was monoclonal was tested by carrying out PCR repertoire analysis using a series of 26 human V β gene segment primers. Only one of 26 primers gave a significant signal, the V β 13.1 primer, thereby demonstrating the apparent monoclonality of the 3-3F4 T cell clone.

To identify the precise epitope or peptide recognized by the T cell clone 3-3F4, a series of vaccinia truncations that deleted the pp65 protein from the carboxyl towards the amino terminus was used. A CRA utilizing autologous and HLA mismatched LCL as targets, infected with vaccinia viruses expressing truncation products of the pp65 protein, was conducted. This experiment localized a region between amino acids 377 and 561 that was necessary for killing of targets.

Utilizing a small subset of amino terminal deletions, the region necessary for killing was further localized between amino acids 477 and 561. Utilizing an indirect killing assay, a monkey kidney cell line was

5 transfected with the molecular HLA allele HLA A*0201 and portions of the pp65 gene to localize the region to a fragment containing amino acids 452-561. The final determination of the peptide sequence that corresponds to the sequence bound by HLA A*0201, and is recognized

10 by T cell clone 3-3F4 was done by producing 9-10 amino acid peptides on the Synergy (Applied Biosystems Model 432) peptide synthesis machine. Using published information, a series of candidate sequences were determined that had significant characteristics of an

15 HLA A*0201 binding sequence, and were located in the region between amino acid 452-561. These are:

Table 1

| Amino Acid Sequence of Peptide | Position Number | Motif | Score* |
|--------------------------------|-----------------|--------|--------|
| ILARNLVPMV (SEQ ID NO:10) | 491 | A*0201 | 67 |
| ELEGVWQPA (SEQ ID NO:11) | 526 | A*0201 | 59 |
| RIFAELEGV (SEQ ID NO:12) | 522 | A*0201 | 55 |
| NLVPMVATV (SEQ ID NO:1) | 495 | A*0201 | 63 |

*(adapted from J. D'Amato et al., "A computer program for predicting possible cytotoxic epitopes based on HLA Class I peptide binding motifs," Human Immunology 43:13-18 (1995)).

Only one of these peptides (referred to as "the 495 peptide" or as "pp65₄₉₅₋₅₀₃") (SEQ ID NO:1) proved capable of priming the autologous LCL to be recognized and killed by the CD8⁺ CTL 3-3F4. Other 9-10 amino acid

5 peptides from pp65 that also followed the HLA A*0201 motif were tested in the CRA. None showed any activity. All peptides were examined by HPLC on a Vydac C₁₈ column using acetonitrile/TFA as the moving

phase. They were 70-80% pure or greater on average, and were used as dilutions from 0.1% acetic acid solution.

5 Example 5. Use of the 495 Peptide To
 Induce Cell Lysis

Serial dilutions of the 495 peptide showed no change in activity between 10 μ M and 0.01 μ M in priming the autologous LCL for killing by T cell clone 3-3F4 in a CRA. Half-maximal lysis occurred at close to 0.5 nM peptide. The peptide-transporter deficient cell line T2 (D.B. Crumpacker et al., J. Immunol. 148:3004-3011 (1992)), which is HLA A*0201 positive, also was used to test the lower limits of sensitivity of the 3-3F4 T cell clone for recognition of the peptide in a CRA. It was found that as little as 0.1 nM peptide caused maximal lysis of T2 cells, equivalent to the condition with 10 nM peptide. These experiments demonstrate that this minimal cytotoxic epitope is a strong binder to the HLA A*0201 allele.

20 The 495 peptide depicted in Table 1 was prepared on a Synergy (Applied Biosystems Model 432) peptide synthesis machine. Dermal fibroblasts were primed with the peptide, then loaded with chromium-51 via the following procedure. Dermal fibroblasts were incubated with 10 μ M of the 495 peptide for 2 hours at 37° C, and for the final hour with chromium-51. The peptide and chromium-51 were washed out of the medium.

30 T cell clone 3-3F4 (CD8⁺ CTL) derived from an HCMV seropositive individual (HLA A*0201 positive) as described above was capable of recognizing the HCMV-infected fibroblasts as well as the peptide-primed fibroblasts in a CRA. Uninfected and unprimed fibroblasts were not recognized or killed by the T cell

TNF- α is a T cell lymphokine that is cytotoxic for many cell types and may contribute to the in vivo immune response mounted against an HCMV infection.

Peptide-primed fibroblasts induced the production of as great or greater levels of TNF- α from T cell clone 3-3F4 as were the HCMV-infected fibroblasts. The inventive 495 peptide did not induce TNF- α production by either autologous fibroblasts incubated without T cells or non-HLA-A*0201 expressing fibroblasts incubated with the T cell clone.

Example 7. 495 Peptide can induce CTL from PBL
of HCMV Seropositive Individuals

PBL from HCMV-seropositive individuals were plated onto 495 peptide-primed autologous fibroblasts for 7
5 days. The once-stimulated PBL were re-stimulated in a similar manner, either with or without depletion of CD4 T cells. After two weeks, a CRA was performed using as targets either peptide-primed, CMV-infected, or
10 untreated autologous fibroblasts. CD8⁺ T cells lysed significant percentages of the peptide primed and CMV infected fibroblasts, but not untreated cells. No autologous fibroblast targets were lysed by CD4-depleted PBL from freshly drawn blood under the same conditions.

15 Example 8. Human Cell Lines Which Express HLA
A2, With Molecular Subtypes Other
Than A*0201, Are Sensitized to
Lysis by The 495 Peptide

Twelve cell lines were subjected to CRA in which
20 they were pulsed with the 495 peptide (pp65₄₉₅₋₅₀₃) nonamer, loaded with chromium-51, and incubated with two different HLA A*0201 restricted CTL which recognize the 495 peptide and HCMV. The specific cytotoxicity was calculated and is shown in tabular form below for the 1
25 μ M and 1 nM concentrations of the 495 peptide. A plus sign (+) represents cytotoxicity greater than 30%, a plus/minus sign (+/-) represents cytotoxicity between 15% and 30%, and a minus sign (-) represents cytotoxicity less than 15%.

Table 2

| HLA A2 Subtype | CTL 3-3F4 | | CTL VB-57 | |
|----------------|-----------|-----|-----------|-----|
| | 1 μ M | 1nM | 1 μ M | 1nM |
| A*0201 | + | + | + | + |
| A*0202 | + | - | + | - |
| A*0203 | + | - | - | - |
| A*0204 | + | + | + | + |
| A*0205 | + | - | + | + |
| A*0206 | + | + | + | + |
| A*0207 | + | + | + | + |
| A*0209 | + | - | + | - |
| A*0210 | + | + | + | + |
| A*0211 | + | - | + | +/- |
| A*0217 | + | - | + | + |

The data show that all tested subtypes functionally bind the 495 peptide at 1 μ M, and the cell lines are lysed by the HCMV and pp65 specific CTL. This data shows that the cell line subtypes shown here are capable of being sensitized for lysis by the 495 peptide. The data also indicate that cells from individuals who carry these subtypes can be sensitized by the peptide for CTL recognition and lysis, albeit at a higher concentration in most cases than what was found for HLA A*0201. Thus, individuals who carry any of these HLA A2 subtypes may respond to the 495 peptide as a vaccine.

Example 9. Animal Studies Using The
 495 Peptide (SEO ID NO:1)

A transgenic mouse model, the HLA A2.1 mouse (E.J. Bernhard et al., J. Exp. Med. 168:1157-1162 (1988)),
5 was employed to test whether the 495 peptide could stimulate CTLp lacking prior virus exposure and function as a vaccine. Three mice were immunized subcutaneously at the base of the tail with 50 µg of the 495 peptide (pp65₄₉₅₋₅₀₃) or peptide p53₁₄₉₋₁₅₇ from p53
10 (M. Theobald et al., Proc. Natl. Acad. Sci. U.S.A. 92:11993-11997 (1995)) together with 20 µg of the polyclonal helper T lymphocyte (HTL) peptide (PADRE) (J. Alexander et al., Immunity. 1:751-761 (1994)) emulsified in IFA (Incomplete Freund's Adjuvant).
15 After twelve days, spleens were removed from immunized mice, a splenic suspension was made, and the effector cells were restimulated for one week using p53₁₄₉₋₁₅₇ or pp65₄₉₅₋₅₀₃ peptide sensitized syngeneic lipopolysaccharide-treated splenic blast cells (P.A. Wentworth et al., Eur. J. Immunol. 26:97-101 (1996)).
20 Thereafter, for subsequent in vitro stimulations, the stimulator cells were Jurkat A2.1 cells, prepared by acid treatment and subsequent loading of peptides (Z. Yu et al., Journal of Surgical Research 69:337-343 (1997)).
25 After two in vitro restimulation cycles, the murine splenic effector population was tested for recognition of p53₁₄₉₋₁₅₇ or pp65₄₉₅₋₅₀₃ peptide loaded T2 cells. There was substantial recognition of pp65₄₉₅₋₅₀₃ or p53₁₄₉₋₁₅₇ peptide in mice that had been appropriately
30 immunized, without recognition of the non-immunizing peptide.

It was also demonstrated that murine splenic effectors recognize endogenously processed pp65 in a CRA with human HLA A*0201 EBVLCL targets infected with

pp65Vac (D.J. Diamond et al., Blood 90 (5):1751-1767 (1997)). Further proof that the pp65₄₉₅₋₅₀₃ peptide causes recognition of virus-infected cells came from a CRA using HCMV-infected human fibroblasts as targets, and murine CTL derived from the pp65₄₉₅₋₅₀₃ peptide stimulation as the effector population. HLA A*0201 fibroblasts infected with HCMV were capable of lysis by the CTL, whereas both uninfected and mismatched fibroblasts were not recognized (D.J. Diamond et al. Blood 90 (5):1751-1767 (1997)). Taken together, these results clearly show that the splenic effector population from a primary immunization with pp65₄₉₅₋₅₀₃ are recognizing endogenously processed pp65 and HCMV in an HLA A*0201 restricted manner.

An additional study demonstrated that the 495 peptide can induce a long-lived immune response in animals. Twelve mice were simultaneously immunized with the 495 peptide + PADRE + IFA, and two additional mice were immunized with HTL + IFA alone. At two weeks, 6 weeks, 10 weeks and 14 weeks after the immunization, the spleens from two immunized mice were analyzed for immunity against the 495 peptide or a control peptide from human p53 (p53₁₄₉₋₁₅₇). In addition, at two and six weeks, mice immunized without the 495 peptide were also sacrificed and their spleen cells analyzed for immune responses against the 495 peptide or the human p53 peptide. Percent specific cytotoxicity (cytotoxicity of 495 peptide targets - cytotoxicity of p53 targets) was still at a level of 40% after 14 weeks, whereas naive animals did not show any specific cytotoxicity above 5%. This compared well with recent results from immunizing human volunteers with the Theradigm™ lipopeptide (B. Livingston et al., J. Immunol. 159:1383-1392 (1997)) in which there was an average maintenance of 60% of the initial response

weeks after the final of four immunizations over an eighteen week period.

5 Example 10. Lipidated Peptides Incorporating
 pp65₄₉₅₋₅₀₃ (SEQ ID NO:1) as IFA-
 Adjuvant Independent Vaccines in
 Animals

10 Although the use of adjuvants to enhance
 immunogenicity is a common strategy in animal studies,
 there are important limitations concerning their use in
15 humans. To avoid having to use adjuvants, peptides
 which incorporate lipid molecules were prepared. This
 strategy has been efficacious in both animal (K. Deres
 et al., Nature 342:561-564 (1989)) and human clinical
 studies (A. Vitiello et al., J. Clin. Invest. 95:341-
20 349 (1995)).

 Either one or two palmitic acid moieties were
 attached to the amino terminus of the 495 peptide, and
 a series of immunization studies was conducted in the
 transgenic HLA A2.1 mouse. The primary structure of
25 the directly lipidated peptides is shown in Table 3.

**Table 3 Primary Structure of Peptides Used to Immunize
HLA A2.1 Transgenic Mice**

| Lipid Molecule(s) | Adaptor Sequence | Epitope Sequence (SEQ ID NO:1) | Carboxyl Terminus |
|-------------------|---------------------|-----------------------------------|----------------------|
| 0 | -KSS- | -NLVPMVATV- | OH |
| 1 PALMITIC ACID | -KSS- | -NLVPMVATV- | OH |
| 2 PALMITIC ACID | -KSS- | -NLVPMVATV- | OH |

30 **Table 3.** Peptides were synthesized on the ABI 432
 (Applied Biosystems), and purified and analyzed as
 described (D.J. Diamond et al., Blood 90 (5):1751-1767
 (1997)). Palmitic acid (Aldrich) was dissolved in
 dimethylformamide, and automatically coupled to the

amino terminal lysine. The amino terminal lysine of the monolipidated form of the peptide was protected by two protecting groups, Fmoc and Boc. Only the Fmoc group is cleaved during synthesis to allow for a single lipid moiety to be added. For the dilipidated form, the amino terminal lysine was protected with two Fmoc groups, therefore allowing two lipid moieties to be added. Peptides also may be lipidated at other locations by methods well known in the art.

Separate mice were immunized with unmodified pp65₄₉₅₋₅₀₃, and either the monolipidated or dilipidated forms of the peptide together with the PADRE epitope. Because it has been previously shown that lipidated peptides will stimulate immunity without co-administration of Freund's adjuvant (H. Schild et al., Eur. J. Immunol. 21:2649-2654 (1991)), immunization of mice with and without emulsifying the peptides in IFA was compared. In a procedure similar to the procedure described in Example 9 above, twelve days post inoculation the mice were splenectomized and the spleen cell population was restimulated twice in vitro. The splenic effectors were then tested in a CRA with peptide-loaded T2 cells, EBVLCCL targets infected with pp65Vac, and HCMV-infected fibroblasts (D.J. Diamond et al., Blood 90 (5):1751-1767 (1997)). The results demonstrate that the lipidated form of the 495 peptide, without emulsification in adjuvant, induces an immune response capable of recognizing endogenously-processed pp65 and HCMV-infected human cells. The monolipidated form appeared to induce a weaker immune response (compare with and without IFA), whereas the unmodified free peptide had no activity unless emulsified in IFA. (See Fig. 1)

These data illustrate an advantageous immunization/vaccination procedure for use in warm

blooded animals including humans. The procedure entails the mixture of two peptides in an aqueous solvent system (the lipidated 495 peptide plus either PADRE or the 830-843 amino acid tetanus peptide, Table 3). The mixture is administered subcutaneously or via another acceptable and efficacious route to either HCMV seropositive or seronegative subjects. An additional set of booster injections may be employed to enhance the immunity induced by primary vaccination.

Example 11. Formulation of Lipidated Vaccines

The 495 peptide and functional sequence variants thereof can be formulated as a vaccine as a lipidated peptide with a covalent HTL epitope. The HTL epitope can be any peptide that has broad reactivity to human MHC class II to stimulate a classic helper response. Such molecules include but are not limited to amino acids 830-843 from tetanus toxin (P. Panina-Bordignon et al., Eur. J. Immun. 19:2237-2242 (1989)), HTL epitopes from HIV envelope protein (J.A. Berzofsky et al., J. Clin. Invest. 88:876-884 (1991)), or a synthetic version (PADRE) predicted from known anchor residues (J. Alexander et al., Immunity 1:751-761 (1994)).

The lipidation of the HTL+CTL epitope preferably is performed on the amino terminus of the HTL epitope, with the HTL epitope being amino terminal to the CTL epitope. Suitable lipid moieties are known and described in the literature. (H. Schild et al., Eur. J. Immunol. 21:2649-2654 (1991); A. Vitiello et al., J. Clin. Invest. 95:341-349 (1995); K. Deres et al., Nature 342:561-564 (1989)). Alternatively, the CTL epitope can be lipidated at its amino terminus, followed by the HTL epitope, or the lipid can be found

at the carboxyl terminus followed by either the CTL or HTL epitope(s). A three amino acid spacer can be inserted between the HTL and CTL epitope, or the epitopes can be fused directly in frame. Alternatively the CTL epitope lipidated on its amino terminus can be administered together with the HTL epitope, without covalent attachment. The vaccine epitopes, regardless of primary structure, may be injected s.c. into the forearm in a standard formulation buffer (PBS/10% DMSO or higher concentration/0.01% trifluoroacetic acid or other acid or alcohol of the same or different concentration) once. Three to six weeks later, a booster injection of the same material may be administered. Multiple booster injections spaced three to six weeks apart can be subsequently administered, if necessary.

This injection series can be administered to a patient or at-risk individual, or to the donor of a bone marrow transplant, who is either positive or negative for the virus. Illustrative examples of lipidated vaccine peptides include:

Table 4

| | <u>N-terminal</u> | <u>C-terminal</u> |
|----|---|-------------------|
| 25 | (Pam) ₂ -KSSQYIKANSKFIGITEAAAANLVPMVATV (SEQ ID NO:13) | |
| | (Pam) ₃ -CSSQYIKANSKFIGITEAAAANLVPMVATV (SEQ ID NO:14) | |
| | (Pam) ₂ -KSSAKXVAAWTLKAAAGGGNLVPMVATV (SEQ ID NO:15) | |
| | (Pam) ₃ -CSSAKXVAAWTLKAAAGGGNLVPMVATV (SEQ ID NO:16) | |

wherein X is cyclohexylalanine or phenylalanine. As is the case throughout, all amino acids are represented by their universal one-letter code. "Pam" is palmitic

acid. The three-A or -G spacer (underlined) can be
interchanged among vaccine peptides. The format of the
peptides shown above can be described (from the amino
terminus) as: lipid-K/CSS--HTL epitope (*italics*)--amino
5 acid spacer (underlined)--CTL epitope. The positions
of the CTL and HTL epitopes may be interchanged. The
CTL epitope (or a functional sequence variant thereof)
may be further modified by adding a leader sequence
and/or the amino acids KDEL can be appended to the
10 carboxyl terminus for retention and targeting into the
endoplasmic reticulum. Palmitic acid or any suitable
lipid may be used, including but not limited to stearic
acid, myristic acid, lauric acid, capric acid and
decanoic acid.

15 Example 12. Use of Combined HTL and CTL Epitope,
Lipidated at the Amino Terminus, as a
Single Component Vaccine in Transgenic
Mouse Studies

Two further molecules, each containing lipid, HTL and
20 CTL epitopes, were constructed and tested in mice:

Table 5

N-terminal

C-terminal

A. (Pam)₂-KSSAKXVAAWTLKAAANLVPMVATV (SEQ ID NO:17)

25 B. (Pam)₂-KSSISQAVHAAHAEINEAAANLVPMVATV (SEQ ID NO:18)

Nomenclature for Table 5 can be found in the legend to
Table 4.

Molecule A (SEQ ID NO:17) is a vaccine that has
30 the capability of working in mice and humans, whereas
molecule B (SEQ ID NO:18) should only be functional in

mice. One hundred nanomoles of each of these vaccine peptides in 25% dimethylsulfoxide in phosphate buffered saline with 2.5% hexafluoroisopropanol were injected s.c. into separate transgenic HLA A2.1 mice.

5 The methods referred to in Examples 9 and 10 were used to derive spleen cell populations containing cells which were specific against pp65 and HCMV. The spleen cells from immunized mice were tested for recognition and cytotoxicity against specific and non-specific
10 peptide-sensitized targets, HCMV infected and non-infected HLA A*0201 and HLA-mismatched fibroblast targets. The 495 pp65₄₉₅₋₅₀₃ peptide sensitized targets were effectively lysed, whereas targets sensitized with a peptide derived from another protein (human p53)
15 which binds to HLA A*0201 (p53₁₄₉₋₁₅₇) were ineffective. In addition, and importantly, HCMV-infected HLA A*0201 fibroblasts were effectively lysed, but uninfected fibroblasts or those which are HLA-mismatched were not recognized or lysed, regardless of HCMV infection.
20 These results were obtained with both molecules A and B, although molecule A was the more potent of the two. However, a second immunization (booster) of mice immunized with Vaccine A at lesser amounts of 50 nmole resulted in a detectable immune response when a single
25 immunization was not effective (Table 5). This stimulative effect of the booster is in agreement with B. Livingston et al., J. Immunol. 159:1383-1392 (1997)). These data show that the single molecule form of the vaccine functions to stimulate HCMV immunity in
30 an animal model without any added molecules or adjuvant other than the vaccine molecules A or B (Table 4) in liquid vehicle (PBS/DMSO/HFIP). The data also demonstrate that the vaccine is capable of stimulating a de novo immune response to HCMV in a HCMV-naive
35 mouse.

Example 14. Additional HCMV pp65 CTL Epitopes
 Specific for HLA A and B Alleles

5 The experimental design used to determine the
sequence of the 495 peptide and its function is
described in Examples 1-13. The 495 peptide
specifically bound to HLA A*0201 and the other subtypes
shown in Example 8.

10 There are over 100 known HLA Class I alleles of
the A and B genes, however. (J.G. Bodmer et al., Tissue
Antigens 49:297-321 (1997)). Using a combination of
predictive algorithms and truncation analysis,
additional peptides from pp65 that will sensitize both
autologous and allogeneic cells to be lysed by MHC-
restricted human CTL were identified. As discussed in
15 Example 1, the CTL arise from HCMV seropositive humans;
therefore, the defined epitopes from pp65 were those
used by humans to suppress endogenous HCMV reactivation
or viremia. To define CTL reactive against HCMV pp65
in combination with specific HLA alleles, individual
20 cloned CTL lines were tested for recognition of EBVLCL
infected with pp65vac which contained one of the HLA A
or B alleles found in the individual whose blood was
used to derive the CTL. In cases where at least one HLA
allele is shared between the EBVLCL targets and the
25 CTL, sensitization for recognition and lysis was
observed. This experiment was repeated with at least
three independent cell lines containing the restricting
allele. Table 6 shows the pp65 epitopes, their HLA
restriction, the number of independent cell lines of
30 the same restriction which were sensitized, and the
method(s) of delineation of the epitopes.

Table 6:

| | HLA A or B Allele Specificity | Number of Test Cell Lines | Method(s) of Determination | Minimal Cytotoxic Epitope Sequence |
|----|-------------------------------------|---------------------------------|-------------------------------|---------------------------------------|
| 5 | HLA A*0101 and subtypes | 3 | A, B, C, D, E | YSEHPTFTSQY (SEQ ID NO:3) |
| | HLA A*6801 and subtypes | 3 | A, B, D, E | FVFPTKDVALR (SEQ ID NO:5) |
| 10 | HLA B7 and subtypes | 5 | A, B, D, E | TPRVTGGGAM (SEQ ID NO:7) |
| | HLA B*3502,04, 06 and subtypes | 3 | A, B, C, D, E | FPTKDVAL (SEQ ID NO:9) |

Methods of Determination: (A) HLA Restriction using single HLA allele matched cell lines; (B) pp65 truncations in vaccinia viruses; (C) pp65 truncations in plasmids with detection of activity using TNF- α assay; (D) matching of amino acid residues using published motifs; (E) functional analysis using ordered overlapping peptides.

20 Example 15: Vaccine Molecules Comprised Of
 More than One CTL Epitope

In accordance with the procedures described herein, vaccines containing a combination of pp150 and/or pp65 epitopes, specific for the same or different HLA Class I restriction elements, were prepared. For vaccination of humans there is no necessity for each epitope to have the same MHC restriction. A vaccine molecule which targets two or more MHC restriction elements may be preferred because it allows the production of fewer vaccine molecules, and still ensures that most HLA alleles were targeted in a polymorphic population. Peptides with CTL epitopes which are restricted by frequently expressed HLA alleles (see Tables 1 and 6) are preferred, and

polypeptide vaccines containing epitopes from both the pp65 and pp150 proteins, as well as an HTL epitope, are especially preferred for human vaccination against HCMV. The HLA alleles shown in Tables 1 and 6 are a subset of possible HLA A,B, and C CTL epitopes to be potentially included in a multiple CTL epitope vaccine molecule. The inclusion of multiple CTL epitopes and an HTL epitope will lengthen the peptides (in the range of 40-50 amino acids). Therefore, the hydrophobicity of the sequence is an important factor. Alternatively, HCMV polypeptide vaccines may be prepared without a covalently attached HTL epitope by using multiple CTL epitopes with a spacer of three alanine residues or another combination of amino acids between each epitope, and two palmitic acid-lysyl amides at the N-terminus, as shown in Table 3.

Example 16. Immunization of BMT Patients

A therapeutically active form of an antigenic peptide according to the present invention may be administered to an HCMV-seropositive bone marrow transplant donor at a sufficient time (six to eight weeks, for example) in single or multiple doses separated by a given number of days or weeks prior to bone marrow transplant to enable the development of an anti-HCMV cellular immune response. The antigenic peptide can be formulated in per se known manners (for example, as a lipidated peptide, optionally in combination with a helper peptide and/or an adjuvant) and will be administered, preferably, in multiple doses. If an unmanipulated BMT graft will be given to the recipient, such a graft will contain 25% or more of mature T cells. The T cells will confer active immunity to the BMT recipient patient. Alternatively,

when a T-cell depleted BMT graft is to be employed, an aliquot of T cells from the immunized donor can be administered to the patient following (for example, approximately 21 to 35 days) BMT in order to provide
5 the recipient patient with HCMV immunity.

Example 17. In Vitro Assay For
HCMV Infected Cells

The peptides of the present invention may be used in an in vitro assay to detect the presence or absence
10 of HCMV-infected cells obtained, for example, from a patient who's HCMV status (infected or uninfected) is unknown. T lymphocytes obtained from the patient are incubated with APC primed with a peptide of the present invention. The activation of CTLs or CTLp's will
15 reveal that the patient was infected with HCMV.

Although certain preferred embodiments and examples of the invention have been described, the invention is not so limited. Persons skilled in this field of science will understand that the present
20 invention is capable of wide application in the fields of diagnostics and therapeutics, and that modifications and variations can be made to the invention without departing from its spirit and scope.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

- (i) APPLICANTS: DON JEFFREY DIAMOND and JOANNE YORK
- (ii) TITLE OF INVENTION: IMMUNO-REACTIVE PEPTIDE CTL
EPITOPES OF HUMAN
CYTOMEGALOVIRUS
- (iii) NUMBER OF SEQUENCES: 18
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 - (E) COUNTRY: USA
 - (F) ZIP: 20004
- (v) COMPUTER READABLE FORM:
 - (A) MEDIUM TYPE: Floppy disk
 - (B) COMPUTER: IBM PC compatible
 - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 - (D) SOFTWARE: PatentIn Release #1.0, Version #1.30
- (vi) CURRENT APPLICATION DATA:
 - (A) APPLICATION NUMBER: Unassigned
 - (B) FILING DATE: Concurrently herewith
 - (C) CLASSIFICATION:
- (vii) PRIOR APPLICATION DATA:
 - (A) APPLICATION NUMBER: 08/747,488
 - (B) FILING DATE: 12-NOV-1996
- (viii) ATTORNEY/AGENT INFORMATION:
 - (A) NAME: ATTORNEY, Bart G. Newland
 - (B) REGISTRATION NUMBER: 31,282
 - (C) REFERENCE/DOCKET NUMBER: 1954-112 CIP
- (ix) TELECOMMUNICATION INFORMATION:
 - (A) TELEPHONE: 202-783-6040
 - (B) TELEFAX: 202-783-6031

(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 9 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

Asn Leu Val Pro Met Val Ala Thr Val
1 5

(2) INFORMATION FOR SEQ ID NO:2:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 9 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(ix) FEATURE:

- (A) NAME/KEY: Domain
(B) LOCATION: 2
(D) OTHER INFORMATION: /note= "Xaa = Leu, Ile,
Met, Thr, or Val"

(ix) FEATURE:

- (A) NAME/KEY: Domain
(B) LOCATION: 9
(D) OTHER INFORMATION: /note= "Xaa = Val, Ala,
Cys, Ile, Leu, or Thr"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Asn Xaa Val Pro Met Val Ala Thr Xaa
1 5

(2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 11 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

- (ii) MOLECULE TYPE: peptide

- (v) FRAGMENT TYPE: internal

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

| | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Tyr | Ser | Glu | His | Pro | Thr | Phe | Thr | Ser | Gln | Tyr |
| 1 | | | | 5 | | | | | 10 | |

(2) INFORMATION FOR SEQ ID NO:4:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 11 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

- (ii) MOLECULE TYPE: peptide

- (v) FRAGMENT TYPE: internal

- (ix) FEATURE:

- (A) NAME/KEY: Domain
- (B) LOCATION: 2
- (D) OTHER INFORMATION: /note= "Xaa = Ser, Thr or Leu"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

| | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Tyr | Xaa | Glu | His | Pro | Thr | Phe | Thr | Ser | Gln | Tyr |
| 1 | | | | 5 | | | | | 10 | |

41

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 11 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

Phe Val Phe Pro Thr Lys Asp Val Ala Leu Arg
1 5 10

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 11 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(ix) FEATURE:

- (A) NAME/KEY: Domain
- (B) LOCATION: 2
- (D) OTHER INFORMATION: /note= "Xaa = Val or Thr"

(ix) FEATURE:

- (A) NAME/KEY: Domain
- (B) LOCATION: 11
- (D) OTHER INFORMATION: /note= "Xaa = Leu, Arg or Lys"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

Phe Xaa Phe Pro Thr Lys Asp Val Ala Leu Xaa
1 5 10

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 10 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

| | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Thr | Pro | Arg | Val | Thr | Gly | Gly | Gly | Ala | Met |
| 1 | | | | 5 | | | | | 10 |

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 10 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(ix) FEATURE:

- (A) NAME/KEY: Domain
- (B) LOCATION: 10
- (D) OTHER INFORMATION: /note= "Xaa = Leu, Phe, or Met"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

| | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Thr | Pro | Arg | Val | Thr | Gly | Gly | Gly | Ala | Xaa |
| 1 | | | | 5 | | | | | 10 |

43

(2) INFORMATION FOR SEQ ID NO:9:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 8 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

Phe Pro Thr Lys Asp Val Ala Leu
1 5

(2) INFORMATION FOR SEQ ID NO:10:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 10 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

Ile Leu Ala Arg Asn Leu Val Pro Met Val
1 5 10

(2) INFORMATION FOR SEQ ID NO:11:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 9 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

Glu Leu Glu Gly Val Trp Gln Pro Ala
1 5

(2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 9 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

Arg Ile Phe Ala Glu Leu Glu Gly Val
1 5

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 29 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

Lys Ser Ser Gln Tyr Ile Lys Ala Asn Ser Lys Phe Ile Gly Ile Thr
1 5 10 15
Glu Ala Ala Ala Asn Leu Val Pro Met Val Ala Thr Val
20 25

(A) LENGTH: 29 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: not relevant

(v) FRAGMENT TYPE: internal

Cys Ser Ser Gln Tyr Ile Lys Ala Asn Ser Lys Phe Ile Gly Ile Thr
1 5 10 15
Glu Ala Ala Ala Asn Leu Val Pro Met Val Ala Thr Val
20 25

(A) LENGTH: 28 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: not relevant

(v) FRAGMENT TYPE: internal

(A) NAME/KEY: Domain
 (B) LOCATION: 6
 (D) OTHER INFORMATION: /note= "Xaa =
 cyclohexylalanine or phenylalanine"

Lys Ser Ser Ala Lys Xaa Val Ala Ala Trp Thr Leu Lys Ala Ala Ala
1 5 10 15

Gly Gly Gly Asn Leu Val Pro Met Val Ala Thr Val
20 25

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 28 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(ix) FEATURE:

- (A) NAME/KEY: Domain
- (B) LOCATION: 6
- (D) OTHER INFORMATION: /note= "Xaa =
cyclohexylalanine or phenylalanine"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

Cys Ser Ser Ala Lys Xaa Val Ala Ala Trp Thr Leu Lys Ala Ala Ala
1 5 10 15
Gly Gly Gly Asn Leu Val Pro Met Val Ala Thr Val
 20 25

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 25 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(ix) FEATURE:

- (A) NAME/KEY: Domain
- (B) LOCATION: 6
- (D) OTHER INFORMATION: /note= "Xaa =
cyclohexylalanine or phenylalanine"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

Lys Ser Ser Ala Lys Xaa Val Ala Ala Trp Thr Leu Lys Ala Ala Ala
1 5 10 15
Asn Leu Val Pro Met Val Ala Thr Val
 20 25

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 29 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: internal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

| | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Lys | Ser | Ser | Ile | Ser | Gln | Ala | Val | His | Ala | Ala | His | Ala | Glu | Ile | Asn |
| 1 | | | | 5 | | | | 10 | | | | | | 15 | |
| | | | | | | | | | | | | | | | |
| Glu | Ala | Ala | Ala | Asn | Leu | Val | Pro | Met | Val | Ala | Thr | Val | | | |
| | | | | 20 | | | | 25 | | | | | | | |

WE CLAIM:

1. An immunologically active peptide capable of eliciting a cellular immune response to human cytomegalovirus comprising a peptide selected from the group consisting of $NX_1VPMVATX_2$, wherein X_1 is L, I, M, T, or V and X_2 is V, A, C, I, L or T (SEQ ID NO: 2);
5 YXEHPTFSQY, wherein X is S, T or L (SEQ ID NO: 4);
FX₁FPTKDVALX₂, wherein X_1 is V or T and X_2 is L, R, or K (SEQ ID NO: 6); TPRVTGGGAX, wherein X is L, M, or F
10 (SEQ ID NO: 8); and FPTKDVAL (SEQ ID NO: 9).
2. An immunologically active peptide according to claim 1, having the sequence $NX_1VPMVATX_2$, wherein X_1 is L, I, M, T, or V and X_2 is V, A, C, I, L or T (SEQ ID NO: 2).
- 15 3. An immunologically active peptide according to claim 2, having the sequence NLVPMVATV (SEQ ID NO: 1)
4. An immunologically active peptide according to claim 1, having the sequence YXEHPTFSQY, wherein X
20 is S, T or L (SEQ ID NO: 4).
5. An immunologically active peptide according to claim 4, having the sequence YSEHPTFTSQY (SEQ ID NO: 3)
6. An immunologically active peptide according to claim 1, having the sequence FX₁FPTKDVALX₂, wherein
25 X_1 is V or T and X_2 is L, R, or K (SEQ ID NO: 6).

7. An immunologically active peptide according to claim 6, having the sequence FVFPTKDVALR (SEQ ID NO: 5).

5 8. An immunologically active peptide according to claim 1, having the sequence TPRVTGGGAX, wherein X is L, M, or F (SEQ ID NO: 8).

9. An immunologically active peptide according to claim 8, having the sequence TPRVTGGGAM (SEQ ID NO: 7).

10 10. An immunologically active peptide according to claim 1, having the sequence FPTKDVAL (SEQ ID NO: 9).

15 11. An immunologically active peptide according to claim 1, wherein the immunologically active peptide is lipidated.

12. An immunologically active peptide according to claim 11, wherein the immunologically active peptide is monolipidated.

20 13. An immunologically active peptide according to claim 11, wherein the immunologically active peptide is dilipidated.

14. A vaccine against human cytomegalovirus comprising an immunologically active peptide of claim 1.

25 15. A cellular vaccine against human cytomegalovirus comprising antigen presenting cells that have been treated in vitro so as to present an

immunologically active peptide of claim 1 on their surface.

16. A cellular vaccine against human cytomegalovirus of claim 15 wherein the antigen presenting cells are autologous.

17. A cellular vaccine against human cytomegalovirus of claim 15 wherein the antigen presenting cells are allogeneic.

18. An antigen presenting cell prepared by contacting a cell expressing a cell surface antigen HLA molecule with an immunologically active peptide according to claim 1.

19. An antigen presenting cell according to claim 18, wherein the cell surface antigen HLA molecule is A*0201.

20. A viral vector containing a DNA sequence encoding an immunologically active peptide of claim 1.

21. A viral vector of claim 20, wherein the viral vector is derived from a eukaryotic virus.

22. A viral vector of claim 21, wherein the viral vector is derived from vaccinia virus.

23. A viral vector of claim 21, wherein the viral vector is derived from canarypox.

24. A method of augmenting the immune system response to human cytomegalovirus infection of an individual in need thereof, comprising administering to

said individual an immunologically active peptide according to claim 1.

25. A method of augmenting the immune system response to human cytomegalovirus infection of an individual in need thereof, comprising administering to said individual a cellular vaccine according to claim 15.

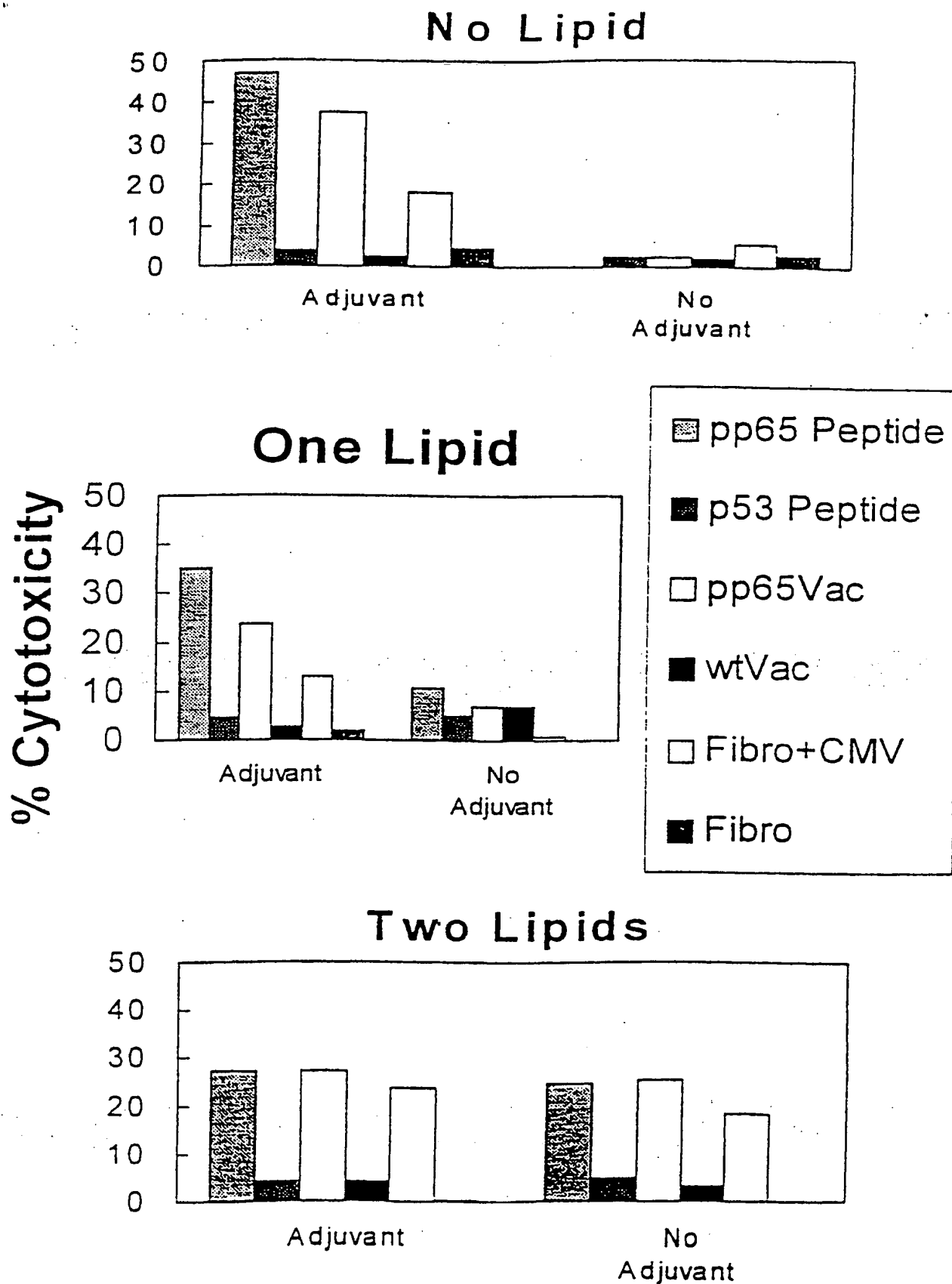
26. A method of providing immunity against human cytomegalovirus to an individual in need thereof, comprising administering to said individual an immunologically active peptide according to claim 1.

27. A method of providing immunity against human cytomegalovirus to an individual in need thereof, comprising administering to said individual a cellular vaccine according to claim 15.

28. A method of protecting an individual having a latent infection of human cytomegalovirus from reactivation of the infection comprising administering to said individual an immunologically active peptide according to claim 1.

29. A method of protecting an individual having a latent infection of human cytomegalovirus from reactivation of the infection comprising administering to said individual the cellular vaccine according to claim 15.

30. A method of determining the presence or absence of human cytomegalovirus-infected T lymphocytes in a sample containing T lymphocytes, comprising contacting T lymphocytes in said sample with an antigen





INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

| | | |
|---|-----------|---|
| (51) International Patent Classification 6 : C07K 14/045, C12N 15/86, A61K 39/00, G01N 33/569 | A3 | (11) International Publication Number: WO 98/21233 (43) International Publication Date: 22 May 1998 (22.05.98) |
| (21) International Application Number: PCT/US97/20236 (22) International Filing Date: 12 November 1997 (12.11.97) (30) Priority Data: 08/747,488 12 November 1996 (12.11.96) US 08/950,064 14 October 1997 (14.10.97) US (71) Applicant: CITY OF HOPE [US/US]; 1500 East Duarte Road, Duarte, CA 91010-0269 (US). (72) Inventors: DIAMOND, Don, Jeffrey; 415 N. Elwood Avenue, Glendora, CA 91741 (US). YORK, Joanne; 40587 174th Street East, Lancaster, CA 93535 (US). (74) Agents: NEWLAND, Bart, G. et al.; Rothwell, Figg, Ernst & Kurz, Suite 701 East, 555 13th Street N.W., Columbia Square, Washington, DC 20004 (US). | | (81) Designated States: CA, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> (88) Date of publication of the international search report: 29 October 1998 (29.10.98) |
| (54) Title: IMMUNO-REACTIVE PEPTIDE CTL EPITOPES OF HUMAN CYTOMEGALOVIRUS (57) Abstract The invention provides a plurality of peptides (and immunologically functional variants thereof) which are immunogenic epitopes recognized by CD8 ⁺ class I MHC restricted cytotoxic T-lymphocytes of patients harboring latent cytomegalovirus (HCMV) infection. The peptides are capable of activating CTLs and CTLp's in the absence of active viral replication, and thus are useful for eliciting a cellular immune response against HCMV by normal and immunodeficient subjects. Polypeptide and lipopeptide vaccines, with and without adjuvants, also are disclosed. | | |

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/20236

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C07K14/045 C12N15/86 A61K39/00 G01N33/569

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C07K A61K G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|--------------------------|
| X | WO 94 00150 A (HOPE CITY ; PANDE HEMA (US); RIGGS ARTHUR D (US); ZAIA JOHN A (US)) 6 January 1994 | 1, 11-37 |
| Y | see the whole document | 11-37 |
| X | WILLS E.A.: "The human CTL response to Cytomegalovirus is dominated by structural protein pp65:" JOURNAL OF VIROLOGY, vol. 70, no. 11, November 1996, pages 7569-7579, XP002060343 | 1-3, 6-10, 18, 30, 33-37 |
| Y | The whole document; see especially Table 3 | 11-37 |
| | -/- | |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search

20 August 1998

Date of mailing of the international search report

10. 09. 1998

Name and mailing address of the ISA

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Authorized officer

Groenendijk, M

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/20236

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|---|-----------------------|
| X | PARKER E.A.: "Scheme for ranking potential HLA-A2 binding peptides based on independent binding of individual peptide side-chains" JOURNAL OF IMMUNOLOGY, vol. 152, 1994, pages 163-175, XP002075119 BALTIMORE US see table II | 1-3 |
| X | ----- PANDE E.A.: "HCMV strain Towne pp65 gene: nucleotide sequence and expression in E coli" VIROLOGY, vol. 182, 1991, pages 220-228, XP000561310 see page 224 | 1 |
| X | ----- TSUNODA E.A.: "Serologically identical HLA B35 alleles which do not cross-present minimal cytotoxic epitopes to CD8+ CTL" J.CELL.BIOCHEM., vol. suppl.0(19A), 1995, page 298 XP002060345 Abstr.No.J2-218 | 1,20-22 |
| P,X | ----- DIAMOND E.A.: "Development of a candidate HLA A*0201 restricted peptide based vaccine against HCMV infection" BLOOD, vol. 90, no. 5, 1 September 1997, pages 1751-1767, XP002060346 see the whole document | 1-3, 11-37 |
| P,X | ----- KHATTAB E.A.: "Three T-cell epitopes within the C-terminal 265 amino acids of the matrix protein pp65 of HCMV recognized by human lymphocytes" J.MED.VIROL., vol. 52, no. 1, May 1997, pages 68-76, XP002075120 See especially page 71, column 1 and Table IV | 1,4,5, 11-37 |
| A | ----- DERES E.A.: "In vivo priming of virus-specific cytotoxic T lymphocytes with synthetic lipopeptide vaccine" NATURE, vol. 342, 30 November 1989, pages 561-564, XP002060344 LONDON GB cited in the application see the whole document | 11-13 |
| | ----- -/-- | |

INTERNATIONAL SEARCH REPORT

Int. .onal Application No

PCT/US 97/20236

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| A | <p>GONCZOL E ET AL: "Preclinical evaluation of an ALVAC (canarypox)-human cytomegalovirus glycoprotein B vaccine candidate" VACCINE, vol. 12, no. 13, August 1995, page 1080-1085 XP004057496</p> <p style="text-align: center;">-----</p> | 20,21,23 |

INTERNATIONAL SEARCH REPORT

Int. application No.
PCT/US 97/20236

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
Although claims 24-29 and 31-33 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1,11-37(all partially); 2,3 (all completely)

Peptides as defined in the claim 1 comprising the sequence NX1VPMVATX2, pharmaceutical compositions comprising these peptides, cellular vaccine as defined in claim 15 as far as relating to said peptides, their medical and diagnostical use and a viral vector comprising DNA coding for said peptides.

2. Claims: 1,11-37(all partially); 4,5 (all completely)

Peptides as defined in the claim 1 comprising the sequence YXEHP TFSQY, as far as not covered by subject 1, pharmaceutical compositions comprising these peptides, cellular vaccine as defined in claim 15 as far as relating to said peptides, their medical and diagnostical use and a viral vector comprising DNA coding for said peptides.

3. Claims: 1,11-37(all partially); 6,7,10 (all completely)

Peptides as defined in the claim 1 comprising the sequence FX1FPTKDVALX2, as far as not covered by subjects 1-2, pharmaceutical compositions comprising these peptides, cellular vaccine as defined in claim 15 as far as relating to said peptides, their medical and diagnostical use and a viral vector comprising DNA coding for said peptides.

4. Claims: 1,11-37(all partially); 8,9 (all completely)

Peptides as defined in the claim 1 comprising the sequence TPRVTGGGAX, as far as not covered by subjects 1-3, pharmaceutical compositions comprising these peptides, cellular vaccine as defined in claim 15 as far as relating to said peptides, their medical and diagnostical use and a viral vector comprising DNA coding for said peptides.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 97/20236

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|----------------------------|---------------------|
| WO 9400150 A | 06-01-1994 | CA 2117181 A | 06-01-1994 |
| | | AU 675204 B | 30-01-1997 |
| | | AU 2297292 A | 24-01-1994 |
| | | EP 0605432 A | 13-07-1994 |
| | | JP 6510799 T | 01-12-1994 |